LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although portions of this report are not reproducible, it is being made available in microfiche to facilitate the availability of those parts of the document which are legible.

3

LA-UR -88-1992

Received by OSTI

AUG 0 4 1988

TITLE: INFORMATION MANAGEMENT IN THE DESIGN OF MATERIALS CONTROL AND ACCOUNTABILITY SYSTEMS

LA-UR--88-1992

DE88 014434

AUTHOR(S): W. J. Whitty,

SUBMITTED TO: 29th Annual Meeting of the Institute of Nuclear Materials Management, Las Vegas, June 26-29, 1988

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO. 836 R4
ST. NO. 2629 5/81

INFORMATION MANAGEMENT IN THE DESIGN OF MATERIALS CONTROL AND ACCOUNTABILITY SYSTEMS

William J. Whitty, Jack T. Markin, and Richard B. Strittmatter
Safeguards Systems Group
Los Alamos National Laboratory
Los Alamos, NM 87544

ABSTRACT

In the initial stage of a materials accounting system design, fundamental decisions are made about the data to be acquired, the means for acquisition, and the location and timing of the acquisition. The data to be acquired are determined by their intended use in the analysis, reporting, and decision processes. This paper presents information management methods for materials accounting systems based on experience in system development at DOE facilities. Specifically, we describe principles for the acquisition and organization of data for a materials control and accountability (MC&A) system. Many of these principles are drawn from software engineering. These include the preparation of a requirements document, a functional specification, and the application of structured analysis and design. Our experience shows that insufficient effort and detail to these early fundamental activities for identifying and acquiring the appropriate data cause many problems later. Failure to provide for complete acquisition of all required information leads to potentially costly revisions to the data acquisition system or to a materials accounting system that cannot complete its intended functions. Likewise, unrealistic analyses requirements can cause catastrophic problems later on. The results of this research should produce a functional description of a modern MC&A system to serve as a guide for developing or upgrading MC&A systems.

INTRODUCTION

A nuclear materials control and accountability (MC&A) system is a fundamental part of a graded safeguards program as required by Department of Energy (DOE) Order 5633 series[1] for all special nuclear materials (SNM) under the control of a facility. The MC&A system consists of measurement instruments, data processing hardware and software, and a set of procedures that provide for the development of timely information on the location and status of nuclear material. The procedures provide for the collection of the right data and for the means for transforming these data to information usable by safeguards personnel. Safeguards as a whole and the design of an MC&A system in particular are strongly affected by the process design and operation. Usually, safeguards are considered after the process is designed and, in some cases, is under construction or complete with its enclosing structures. In a safeguards system considered for upgrading, the fixed features must be handled the best way possible under these constraints. Early entry of safeguards personnel into the process design stage is critical to the design and development of a satisfactory safeguards system. Otherwise it may be difficult to perform the safeguards functions adequately, or they may be performed awkwardly. Without safeguards being considered at the earliest stages of process design, the required data may not be available or may be extremely costly or difficult to acquire. Our experience shows that insufficient effort and detail to these early fundamental activities for identifying and acquiring the appropriate data, such as the addition of measurement instruments, communication lines, computer hardware, and software revisions.

Designing a materials accounting system consists of creating an information-management system that acquires relevant data on the materials-related activities within the facility, organizes these data into a database where they are easily retrieved, establishes criteria for detecting anomalies, analyzes the data to ensure that material is accounted for and to detect anomalies in materials-related activities when they occur, resolves anomalies, and reports on the status of materials accounting. Here, we concentrate on the information and data aspects that are extremely important at the earliest design stage. This paper presents information-management methods for materials accounting systems that draw on experience in system development at DOE facilities. Specifically, we describe principles for the acquisition and organization of data for an MC&A system.

FUNDAMENTAL REQUIREMENTS

The primary general safeguards objective is to protect the public and facility employees from

*Work supported by the US Department of Energy, Office of Safeguards and Security.

dangers that could arise from misuse of the facility's equipment and/or its nuclear material. The informational requirement related to this objective is to keep timely information on the location and status of nuclear material subject to control by the facility. The specific meanings of "timely information" and "subject to control" are delineated in the appropriate parts of the DOE Order 5633 series. This information is presented in the form of reports, including data on transactions, inventories, and materials balances. There is no prescribed way of recording data; however, it must be able to be retrieved according to a materials balance area (MBA) reflecting the quantities of nuclear material that have been shipped, received, or otherwise removed from an MBA and remaining quantities in inventory. Also, SNM inventory differences must be able to be resolved and programmatic reporting must be satisfied. Material type codes and project numbers are published by DOE and are required for all transactions involving DOE-owned material used in production and research programs. Materials balance, project balance, composition of ending inventory, and scrap reports require the identification of the MBA. Much more data also must be collected, refined and analyzed to provide the information and data required by DOE Headquarters, Operations Offices, and, in some cases, Area Offices. The new performance requirements will place additional demands on the safeguards organizations at these facilities. Data collection are further complicated by the additional informational requirements imposed by the DOE contractor operating the facility.

There is a fundamental difference between the meaning of the words information and data. Notice in the above paragraphs we have used both information and data. They are not used synonymously. Both data and information are necessary for formal reporting. When necessary, these data are converted to information, for example, to resolve inventory differences. In the next section we will focus on the differences between information and data.

INFORMATION AND DATA

In many cases the words "information" and "data" are treated as synonyms, which leads to misunderstandings of what is meant. The following definitions of information and data are the most appropriate selections from the American Heritage Dictionary.[2]

Information: "Knowledge derived from study, experience, or instruction."

Data: "Information, esp.(ecially) information organized for analysis or used as a basis for a decision."

This definition of information is satisfactory because it conveys the idea of knowledge. However, "data" is defined as organized information. This leads to much of the misunderstanding of the meaning of these words in our profession and others.

Now let us examine the definitions of information and data as they are used in the data processing and communication fields. The next definitions of information and data are from the Dictionary of Scientific and Technical Terms[3]

Information: "Data which has been recorded, classified, organized, related, or interpreted within a framework so that meaning emerges."

Data: "Any representations of characters or analog quantities to which meaning, if not information, may be assigned."

The IBM Vocabulary for Data Processing, Telecommunications, and Office Systems gives essentially the same definition of data plus the following definitions.

Data: "A representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by human or automatic means."

Information: "The meaning that a human being assigns to data by means of the conventions applied to that data."

For our purpose, the data processing and communications definitions are appropriate. Let us paraphrase these definitions. Information is data processed according to some convention so that meaning emerges. Data is a representation of facts suitable for interpretation by human or automatic means. For example, a tank level recorder output is a datum (a fact). The level reading can be converted to a volume by some calibration mechanism (another datum but with more meaning). After the transfer of material from the tank, another level reading converted to a volume when arithmetically combined with the previous volume gives the volume transferred from the tank. This is now a piece of information about that particular tank. It is also a piece of the entire data set necessary to close a materials balance around the tank or possibly the appropriate MBA.

These definitions and the concepts they convey are crucial in the early safeguards system design phase to ensure that the information and data will be available for required reporting procedures. In most cases acquiring the required data for reporting to DOE should not present a serious problem. The real problem is how to get the data that are processed to provide information. In many situations in safeguards/facility operations, as well as other fields, the engineers have the tendency to say "let's get everything." This is especially true with processes that have on- and/or in-line instruments controlled by microprocessors with the captured data being stored electronically suitable for digital processing. A final example is appropriate. Limit-of-error (LOE) calculation formulas are composed of a large number of terms representing variances and covariances. The output of a tank level recorder is an electronic signal that uses an internal processor to convert the signal to a level. Let's assume that the error statistics are known for the level data from the manufacturer's published data and that the errors must be propagated from level data. Tanks usually have piecewise-continuous calibration curves giving volume data from level data. The calibration curves have their own error statistics. Now the real data of interest to process personnel are the volume, not the level. The volume is also necessary to provide safeguards information. However, the volume for safeguards error propagation must include error statistics. In designing the plant instrumentation, the engineers may have thought that they have gotten everything by providing a volume measurement. The LOE required cannot be obtained from these data. (Another more practical issue is whether that much detail is really necessary? We address this subject later.)

INFORMATIONAL REQUIREMENTS

Materials accounting informational requirements are available from examining safeguards reports prepared by other organizations at the facility, discussions with the overall safeguards organization, facility standard safeguards procedural documents, and other facility-specific sources. The important issue is to clearly define these requirements and then determine the data needed to produce the information. The means of production should not be considered hastily. This could result in necessary data not being specified and acquired. In most cases the safeguards organization will compile the reports and serve as the facility interface to DOE. The lower-level organization must supply the appropriate information and data for the safeguards organization to function properly. It is generally left to the discretion of the lower-level organization to provide this information and data in the manner that seems most appropriate for the process(es) or plant safeguarded.

Development of the informational requirements into clear, unambiguous statements of what is to be produced is not as simple as most believe. After using all the sources available, as described earlier, communication with the users of the system on what is needed, how they perceive the system will work, and its benefit to them is essential. In a safeguards system the user community may be smaller than for a business system. In addition, the users may be the people who requested the system. Identifying the real users of the system may be difficult. It is possible to be introduced to users who are only substitutes for the real users. The actual users may be too busy to work on requirements and related tasks so someone else is selected to perform these duties. Therefore, the software is developed according to the specifications of these surrogate users who may not understand the real problem. In these days of uncertain economic conditions, all facets of industry and government are relying more and more on temporary workers, who are just the sort of people who could be selected as users. Identifying the real user is perhaps the most important phase of systems design.

No matter what the situation, there will be at least two organizations involved with the system at the local level--the process people and the safeguards people. Constant or frequent communication between these two organizations is absolutely necessary.

Statistical analyses attempt to detect accounting anomalies by testing measurement data to determine if they are more likely to be generated by normal or abnormal conditions. Examples are comparison of a current and previously measured value and of an inventory difference or shipper/receiver difference. Statistical tests and other procedures used to transform data to information should be selected carefully to provide the information required. Specifying complex tests and procedures beyond what is necessary can be costly, both economically and in computer resources. Furthermore they may not provide more information than less complex methods.

Once the informational requirements are determined, they can be converted into system outputs. Do not require more than is necessary; keep it simple. We strongly recommend that the designers concentrate on the required outputs of the system to determine the data necessary to produce them and do not include complicated statistical procedures unless they are absolutely necessary. Spend time defining what is needed.

DESIGN METHODS USED FOR IDENTIFYING DATA

Orr[5] correctly states that any information system can be considered as a set of inputs, a set of outputs, and a set of operations (black boxes) that transform the inputs to outputs. Input and output sets and the black boxes generally are considered under systems requirements. The requirements, however, are primarily concerned with outputs and the logical rules for their derivation. Outputs and inputs can be considered as sets of data. The black box can be considered as either sets of functions or sets of data. Thus, the system is a set of relationships between the sets of functions and sets of data. The major elements of the system are the output, the functions that produce the output, the database, and the input. Orr suggests to start with the output and work backwards through the system until the required processing steps are determined, the database is defined, and finally the inputs that need to be collected are identified. A number of benefits result from working backwards starting with the output data structures. One major benefit is that, in the ideal case, unnecessary data will not be collected or stored. Working backwards is difficult to apply. One of the reasons that it is hard is that it requires goals and objectives be specified and that well thought out decisions be made regarding the data to be collected. On the other hand, considering input is much easier. Hard decisions can be postponed. It is easy to say, "Collect everything; someday it may be needed." In our experience, the latter case is almost always the situation.

Data have three aspects: meaning, composition, and type.[6] Meaning is the role that the thing referred to by the data plays in the system. Composition is elemental or composite. An elemental datum cannot be further decomposed. Elemental data items, or data elements, may take on values. The data composition specification states the names and relationships of the data items when taken together play the role defined by the meaning of the specification. The type is the kind of data, for example, integer, real, or character. Breaking composite data down by stepwise refinement is a common software engineering technique used to develop a data dictionary. It is also useful with limited refinement at an early stage in the requirements phase.

Data can be classified in several ways. One means of classification relates to the potential database structure. Here we are only concerned with the conceptual structure. Other structures are outside the scope of this discussion. The conceptual structure or schema of a database is the name given to to the data structure at the conceptual level. It is completely independent of the computer, the operating system, and the database management system (DBMS). One method of viewing the conceptual structure considers the basic data elements or entities, which represent real things; other data elements called attributes that describe the entities; and associations between the data elements called relationships. This is the well-known entity-relationship (E-R) method.[7-9] Another method is to organize the data based on the assumed or known usage pattern. The E-R method organizes the data as they exist in the real world, whereas the second method organizes data according to their usage. A database structure designed by these methods will be very different. The E-R method will allow flexibility and expansion. The usage method will provide efficiency or speed. Teorey[7] recommends using the E-R method to define the initial information structure and then use the usage method to refine the information structure for processing efficiency. Although this approach is recommended for database design, it can also be used at a high level to understand the data required. It will also serve as a first cut at the database design.

Booth[10] recommends that the system be treated as output driven as much as practicable and then use the E-R approach. Booth is a practitioner, Teorey is an academic. For the early stages of MC&A system design, we recommend Booth's method. However, the more integrated the system becomes, for example, including access control, the more Teorey's approach may be useful in the early stages. Whichever method works better depends on the facility's particular circumstances, its personnel, and the degree of integration of safeguards functions.

Data also can be classified either as static or as dynamic. Static data is relatively permanent and is mainly used for reference and computations during production runs. It is generated or updated infrequently. Examples of static data are calibration constants and error components (variances, covariances) used for LOE calculations. Dynamic data are generated during production runs or is output. Examples of dynamic data are book inventory amounts and values of transferred amounts in transactions. The static and dynamic data elements can be grouped in logical categories according to their usage. These groupings can help to suggest additional data needed. This may be much more useful for static data than dynamic data. It is not easy to know what the static data are because these components are taken for granted or are not considered very often. Look carefully at the static data requirements before stating a need for a computation. Unrealistic requirements can have very serious effects later.

When data are automatically acquired from instruments and possibly an analytical laboratory and are automatically transmitted to a computer, there is a possibility that the data composition, sequence, and format may make it difficult or impossible to assemble the proper data to produce the information needed. The information system should be thoroughly documented in the functional specification (see the Software Design and Development section) before the data composition and format are decided.

Process operations requirements will dictate much of the physical structure and layout of the instruments used in an MC&A system and for process control. Within these constraints judicious selection of MBA and unit process boundaries will go a long way to help provide for the necessary data for MC&A.

The requirements discussed above are related to outputs and the means for attaining them. Transactions, on the other hand, are inputs, the transformation of inputs, and the transformation of data in the database. Our emphasis is on outputs. Software engineering functions will provide the software, or systems architecture, for producing the outputs from the inputs. Our approach generally agrees with Orr and Booth; start with the outputs and work back through the system, identifying the processing steps and database required until the necessary inputs are identified. All this can be accomplished at a fairly high level at first. Further refinement at the earliest stage is necessary only to define the inputs as reasonably as possible. Then the process design engineers will have something definite to use to provide the necessary data, which may be additional to the process data.

Once we have identified the necessary data, its organization using the inherent interrelationships among the data is the most important step in information management. This is the database design stage. Database design is not only a key element in a complex information system, but it is critical to providing required performance, security, and the ability to expand the system. Database design can also benefit from the application of software engineering techniques.

DATABASE DESIGN AND DATABASE MANAGEMENT SYSTEMS

In acquiring and/or designing software for analysis of accounting data, it is important to consider not only the specific logical or statistical analyses to be executed but also the software for extracting the needed data from a potentially complex database. Thus, the organization of the database and the analysis software will interact and influence the data-retrieval software.

A database is a collection of interrelated data stored together to serve multiple users; the data are stored independent of user programs; a common and controlled approach is used for adding, deleting, modifying, and retrieving data; unnecessary redundancy is kept to a minimum.[9] One of the most critical design tasks is structuring the database. The entire set of records for inventory, transactions, measurement control, errors on materials and any other pertinent records constitute the database. It is possible that the database contains all these records (actually combinations of fields from several records) in a few files. This, however, would not make use of the interrelationships among the data. These interrelationships can be used to structure files in an optimal way for ease of processing, reduce storage, and compensate for change and growth. A good design of the database into a number of files making use of the interrelationships among the data and particular facility considerations also will improve data quality. File-oriented systems can be implemented in several different ways. Direct access files can be searched for keys or pointers defined for the search and stored in another file.

Although a number of facilities are using COBOL programs for file handling and others are using FORTRAN, we recommend using a relational DBMS (R-DBMS) as the major software component in an MC&A system augmented by the most appropriate third- and fourth-generation languages. An R-DBMS has the advantages of data availability, data quality, data security, data independence, management control, flexibility, and *ad hoc* reporting. Many R-DBMSs are commercially available with every new version showing increased speed. Some of these products are used in high-volume transaction operations. Recent advances in R-DBMSs and computer networking hardware and software technology have made distributed databases a reality. Major software vendors are placing significant emphasis on providing software for distributed databases. A significant advantage of an R-DBMS, especially in a distributed environment may be in facilitating truly integrated safeguards. A single database, distributed by an organizational function, could include processing; materials accounting; measurement control; materials control; authorization of individuals to data, material, and locations; and physical protection. The rapid compilation and display of all pertinent information could provide decision makers with information that would allow timely detection and rapid resolution of anomalies with less intrusion on normal operations including production functions.

If the E-R method was used at earlier stages for helping to identify and structure data, it can be refined for the design of the database. Recall that the E-R model is a conceptual structure of the database. The relational model is a particular implementation view. However, the relational model can also be used as a conceptual view. A particularly advantageous approach might be to use the E-R and relational views together. We use the terminology in use for DBMS-theory, although the concepts for structuring data also apply for MC&A systems based on other processing modes. However, whatever method is used for database manipulation, the design of the database should make use of the inherent structure of the data. Bad designs are possible with any type of system. Design is important for performance, flexibility, security, data integrity, and data independence.

Relational systems are more forgiving than other implementations for poor design if the design deficiencies are recognized early and if the R-DBMS product has the capability of easy restructuring. This restructuring is possible because relational systems are composed of flat files that are identical in form to the tables we are all familiar with from our school days. Complex data structures are decomposed into flat files, and further decomposition into simpler tables is accomplished by a process of normalization. Normalization is also useful for designing files that will be processed by means other than a R-DBMS. If we recall that records are composed of fields and files are composed of records, we can compare a file to a table. A table, which in relational terminology is called a relation, is composed of rows called tuples and columns called attributes. The rows correspond to record occurrences. The columns in the table, which correspond to record fields, are called attributes whose values are drawn from a common domain, that is, they are of the same type. The tables are related to one another by one or more common attributes being table components. In file terminology this means that some fields occur in more than one record.[7,9] Further discussion of file handling and relational database concepts is beyond the scope of this paper.

We recommend acquiring the most powerful R-DBMS available that can support distributed processing. This probably means an SQL-based system because IBM, the federal government, and ANSI support SQL and most DBMS vendors are either using it or switching to it.

SOFTWARE DESIGN AND DEVELOPMENT

The computer-based, transaction-processing system forms the basis for developing information on the location and status of all nuclear materials at a facility, including inventory, history of material, movement, losses, and management reports. Modern large computer systems are much more complex than those developed previously. Most of the effort in the development and use of computer software is in debugging and maintenance. This effort can be kept to a minimum by analyzing and designing the system using well-developed software engineering techniques.

The first step in designing a new MC&A system or upgrading to an existing one is to develop a requirements document that includes a description of the major functions to be performed by the MC&A system and a description of the facility as it relates to safeguards. The techniques used for analyzing user requirements and designing a system to satisfy these requirements are called structured analysis and design, respectively. Structured analysis uses the requirements document and data flow from the user community to produce a functional specification, a budget, a schedule, and physical requirements for hardware selection. Here the facility description, which defines the material inventories and flows including the sequence of process steps identifying at each stage potential measurement points and other locations for acquiring the data, is used for identifying data flow. Work on the requirements document should begin early in the plant's detailed design phase or when an upgrade to the safeguards system is proposed. Our experience shows that insufficient effort and detail to these early fundamental activities causes many problems later, including data that are not available and software rewrites. Too much time is usually devoted to technical details and not enough on requirements definition, analysis, and design. Significant effort should be devoted to these activities. Much of the requirements definition, analysis, and design is accomplished either hurriedly or not at all so programming can begin.[10]

The functional specification documents the users' requirements for (1) activities to be performed by the system, (2) data needed to perform these activities, and (3) procedures that govern the uses of the data in the activities. It consists of a set of integrated data-flow diagrams, mini-specifications, and a data dictionary. The data-flow diagrams show the division of a large system into smaller components with the interfaces among the components from the users' perspective. The mini-specifications document the processes shown in the data-flow diagrams. The data dictionary documents the interface flows of the data or data items shown on the data-flow diagrams.

Structured design is also a technique of decomposing a large complex problem into smaller, well-defined, easily understood parts of the problem. These subcomponents, or modules, which function as black boxes, should be as independent as possible from other modules. Structured design uses the functional specification to produce structure charts that illustrate the partitioning of the system into modules including their hierarchy, organization, and communication. The structure chart is the main tool that shows the relationship of the modules to one another, their interfaces, and methods of control.

Jackson,[11] Warnier,[12] and Orr[5] maintain that correct program structure is based on the logical structure of the data. Their methods differ from the popular techniques advocated by Yourdon[13,14] as described above. The former suggest that the first step after determining requirements in designing a system is to draw a representation of the logical structure of the inputs and outputs. Then the relationships between the inputs and outputs can be identified. For complex information systems these relationships can be difficult to determine at a high level. They are more appropriately identified in the detailed analysis phase. In addition, this will be an iterative process. The data-structure approach to software design is more appropriate for systems where there is a direct correspondence between input and output data structures. There is no direct correspondence for safeguards software systems. We are recommending looking at data structures for identifying data, not for software engineering.

We are not recommending the full application of <u>any</u> software engineering technique. There is no single correct method. The main idea we are proposing is closely examining the output necessary and using it to determine the input. Likewise, iteration and stepwise refinement will be necessary.

Furthermore, we recommend that the system be implemented in stages. This may sound like heresy to those those data processing professionals who desire to design and implement a large, complex information system as a whole. We also claim that <u>any</u> information system for safeguards is complex. The advantages and disadvantages of the grand-design and staged approaches are too numerous to discuss here. However, we stand by our recommendation.

Most of the classes, software tools, and literature on software engineering are oriented toward business applications and the Yourdon approach. Real-time systems generally are more complex than business systems and the methodologies for their analysis, design, and development are just beginning to emerge in the marketplace.

There is much more to software engineering than is described here. Additional and more specific information on software engineering appears in these proceedings.[15] The interested reader can find introductory material in Reference 16. Ward and Mellor[6] also describe software engineering for real-time systems. However, common sense is a good guide and keep it simple. Also prototyping should be considered.

SUMMARY

In the initial stage of a materials accounting system design, fundamental decisions are made about the data to be acquired, the means for acquisition, and the location and timing of the acquisition. The data acquired are determined by their intended use in the analysis, reporting, and decision processes that are foreseen for the accounting system as specified in the functional requirements. Failure to provide for complete acquisition of all required data leads to potentially costly revisions to the data-acquisition system or to a materials accounting system that cannot complete its intended functions. Likewise, unrealistic analyses requirements can cause catastrophic problems later. The use of software-engineering tools has been found to aid in designing MC&A systems of different sizes by reducing the problems that would otherwise occur. Activities that are critical in the beginning of a safeguards system design include describing the purpose of the system and defining the information needed in a requirements document, identifying the data required including the content, format and sequence, and preparing a functional specification for software design of the system. These activities should be conducted with knowledgeable users of the system and may need iteration.

In informal discussions people have stated, "This is all well and good, but how do you do it?" The only answer we can give is that the definition of requirements and the specification of the input data requires perseverance, discipline, common sense and a fair amount of practical psychology. We are not recommending any particular software engineering method, rather the designers, developers, and users should select any method or combination of methods that makes them feel comfortable. Software engineering consists of much more than has been covered here. Our main concern is to suggest methods for specifying requirements, for using the requirements to define information needed, and for using the information to clearly and unambiguously specify the data required. Nothing we are recommending is "anything extra;" everything can be used in the analysis phase by the application of stepwise refinement. The results of this research should produce a functional description of a modern MC&A system to serve as a guide for developing or upgrading MC&A systems.

ACKNOWLEDGMENT

We thank Sharon L. Hurdle for compiling the manuscript.

REFERENCES

1. Orders 5633.2 - 5633.4, US Department of Energy, Office of Safeguards and Security, Washington, DC (1988).

2. The American Heritage Dictionary: Second College Edition (Houghton Mifflin Co., Boston, 1982).

3. Dictionary of Scientific and Technical Terms, D. N. Lapedes, Editor-in-Chief, 2nd Ed. (McGraw-Hill Book Co., New York, 1978).

4. IBM Vocabulary for Data Processing, Telecommunications, and Office Systems, 7th Ed. (IBM Corp., Poughkeepsie, NY, 1981).

5. Kenneth T. Orr, Structured Systems Development (Yourdon Press, Englewood Cliffs, NJ, 1977).

6. Paul T. Ward and Stephen J. Mellor, Structured Development for Real-Time Systems, Volume 1: Introduction & Tools (Yourdon Press, Englewood Cliffs, NJ, 1985).

7. Toby J. Teorey and James P. Fry, Design of Database Structures (Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982).

8. Jeffrey D. Ullman, Principles of Database Systems, 2nd Ed. (Computer Science Press, Rockville, MD, 1982), pp 11-25.

9. James Martin, Computer Data-Base Organization, 2nd Ed. (Prentice-Hall, Inc., Englewood Cliffs, NJ, 1977).

10. Grayce M. Booth, The Design of Complex Information Systems (McGraw-Hill Book Co., New York, 1983).

11. Michael A. Jackson, Systems Development (Prentice-Hall, Inc., Englewood Cliffs, NJ, 1983).

12. Jean Dominique Warnier, translated by B. M. Flanagan, Logical Construction of Programs, 3rd Ed. (Van Nostrand Reinhold Co., New York, 1976).

13. Edward Yourdon and Larry L. Constantine, Structured Design, 2nd Ed. (Yourdon Press, New York, 1978).

14. Tom DeMarco, Structured Analysis and System Specification (Yourdon Press, New York, 1978).

15. Gail L. Barlich, "Techniques for Developing Reliable and Functional Materials Control and Accounting Software," Nucl. Mater. Manage. XVII (Proceedings Issue) (1988).

16. Software Engineering Handbook, General Electric Company, Corporate Information Systems (McGraw-Hill Book Co., New York, 1986).